TECHNICAL PAPER

Standardized UXO Demonstration Sites

G-Tek Australia PTY Limited – Magnetometer TM-4/Sling

The Magnetometer TM-4 in the sling platform is shown being demonstrated by G-Tek Australia PTY Limited.

The Magnetometer TM-4 in the sling platform *was demonstrated by G-Tek Australia Pty Limited at the Yuma Proving Ground Demonstration Site's Desert Extreme Area. This technical paper contains the results of that demonstration. This is a reference document only and does not serve as an endorsement of the demonstrator's product by the US Army or the Standardized UXO Technology Sites Program.*

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DESERT EXTREME SCORING RECORD NO. 536

Technologies under development for the detection and discrimination of unexploded ordnance (UXO) require testing so that their performance can be characterized. To that end, Standardized Test Sites have been developed at Aberdeen Proving Ground (APG), Maryland and Yuma Proving Ground (YPG), Arizona. These test sites provide a diversity of geology, climate, terrain, and weather as well as diversity in ordnance and clutter. Testing at these sites is independently administered and analyzed by the government for the purposes of characterizing technologies, tracking performance with system development, comparing performance of different systems, and comparing performance in different environments.

The Standardized UXO Technology Demonstration Site Program is a multi-agency program spearheaded by the U.S. Army Environmental Center (USAEC). The U.S. Army Aberdeen Test Center (ATC) and the U.S. Army Corps of Engineers Engineering Research and Development Center (ERDC) provide programmatic support. The program is being funded and supported by the Environmental Security Technology Certification Program (ESTCP), the Strategic Environmental Research and Development Program (SERDP) and the Army Environmental Quality Technology Program (EQT).

Demonstrator's System and Data Processing Description

The hand-held TM-4 magnetometer (MAG) system consists of the following components: a Magnetometer Control Module manufactured by G-TEK (model TM-4), Cs Vapor-type TMI Sensors by Geometrics (model G822AS), a Base-station Magnetometer by G-TEK (model TM-4), Differential Global Positioning System (DGPS) by NovAtel (model Rt-2/OEM-4) and an odometer by G-TEK (model TM-4D).

The TM-4 is a self-contained magnetometer system that may be configured with up to four optically pumped magnetic sensors, each of which records the total magnetic field intensity in units of nT to a resolution of 0.01 nT. These sensors will be mounted in an array oriented perpendicular to the survey direction, permitting up to four sensor transects to be recorded simultaneously in the open terrain with high survey productivity. The proposed sensor separation is 300 mm and ground clearance, 250 mm. The measurement rate from each sensor is selectable from nominally 50 per second at 0.003-nT resolution to 400 per second at 0.08-Nt resolution. The high measurement rate permits effective real-time filtering of 50 to 60 Hz electromagnetic interference prior to recording position or time-based measurements at intervals appropriate to the application (in this case, 50 mm or 10 Hz). The TM-4 interfaces with both the industry-standard real-time kinematic (RTK) differential Global Positioning System (DGPS) and the proprietary cotton thread-based odometer systems. This provides versatile time or position-based positioning that is adaptable to varied terrain and vegetation conditions. A key attribute of the TM-4 is the operating system software, which provides a continuous set of data quality monitors, reducing the need to resurvey and improving data quality. In particular, audio and graphic displays and alarms monitor the quality of sensor signals and position data as well as aid navigation.

A two-person crew operates the TM-4 system. One person carries the sensor array, to which is attached the DGPS antenna and odometer system. The sensor array measures 1500 mm in length by the array width, which in this case is 900 mm. The quad-sensor array weighs 10 kg. The second person operates the navigation and data acquisition hardware, which is carried in a backpack with batteries. This backpack measures 600 by 400 by 250 mm and weighs approximately 12 kg. The user interface is a hand-held personal computer (PC). A 5-meter cable eliminates interference at the sensors from the other hardware and separates the two operators. No specific safety hazards have been identified with the use of this equipment.

Data processing consists of magnetic base-station subtraction, optional band-pass spatial filtering to enhance particular source depths, grading, and imaging. Interpretation of picked anomalies involves classification (by type) and ranking (by probability UXO) using model inversion involving both magnetic remanence and the use of a database of anticipated UXO types. Products are data images and dig sheets conforming to DID OE-005-05.02 standards.

The TM-4 has been used with our odometer system by industry and Australian Department of Defense operators for more than 14 years, and with the DGPS for more than 7 years. The odometer remains the positioning technology of choice in adverse terrains (such as wooded scenarios); the DGPS is preferred in open environments. Combined, they meet the requirements of most situations.

Using DGPS in the Open Area

Where satellite coverage is reliable, the DGPS is the technology of choice and any of the industry-standard RTK systems may be used, although in this program we propose using the NovAtel RT-2 system (Ashtech Z-Extreme as a backup). Our preference is to establish a Global Positioning System (GPS) base station on a monument that is within 1 km of the survey area and to use a radio link to the roving GPS receiver. In the roving instrumentation, sensor data are time-tagged with GPS time, and the transformed DGPS positions (and the raw National Maritime Electronics Association (NMEA) GPS data for backup) are recorded. In this way, sensor data are positioned in post-processing to achieve a position accuracy of better than 5 cm. Prior to starting the survey, the roving GPS is located at a known reference to confirm the integrity of the system and the transformations used. The TM-4 array, in use in an open area, is shown in Figure 1.

Using the Odometer in the Wooded Area

The control grid setup will combine the use of the DGPS and traditional survey techniques. Navigation will be done as described above. However, 5 meters before the start of each new transect, the cotton thread is tied either to vegetation or to a small peg anchored in the ground. When each control line is reached, a distance mark is recorded in the TM-4 prior to moving the cone. At the completion of each survey grid section, the cotton is gathered and removed from the site. In post-processing, linear error distribution delivers positional accuracy that is typically less than 0.1 percent of the distance between control lines (0.1 percent of 25 m delivers 25 mm accuracy, in this case.) Because the odometer is used in more adverse terrain, including forests, protocols have been developed using the electronic notepad facility of the TM-4 for recording the location of obstacles (e.g., trees) and the direction taken around them. Thus, if a UXO is detected close to a tree, for example, the validation team will know which side of the tree to search. Experience over many years surveying in forested conditions has indicated that a root mean square (rms) target position error of less than 300 mm can be anticipated, with the most errors occurring where obstacles are circumvented. These errors are not cumulative and are comparable with the interpreted target position errors achieved using the DGPS.

Performance Summary

Results for the Desert Extreme test broken out by size, depth and nonstandard ordnance are presented in the tables below. Results by size and depth include both standard and non-standard ordnance. The results by size show how well the demonstrator did at detecting/discriminating ordnance of a certain caliber range. The results are relative to the number of ordnance items emplaced. Depth is measured from the geometric center of anomalies.

The Response Stage results are derived from the list of anomalies above the demonstrator-provided noise level. The results for the Discrimination Stage are derived from the demonstrator's recommended threshold for optimizing UXO field cleanup by minimizing false digs and maximizing ordnance recovery. The lower 90 percent confidence limit on probability of detection and Pfp was calculated assuming that the number of detections and false positives are binomially distributed random variables. All results have been rounded to protect the ground truth. However, lower confidence limits were calculated using actual results.

Summary of Desert Extreme Results (Ferrous Only)

Metric	Overall	Standard	Nonstandard	By Size			By Depth, m		
				Small	Medium	Large	< 0.3	0.3 to <1	>= 1
RESPONSE STAGE									
P_d	0.35	0.40	0.35	0.15	0.50	0.70	0.30	0.45	0.40
P_d Low 90% Conf	0.31	0.30	0.25	0.08	0.38	0.54	0.24	0.35	0.11
P_d Upper 90% Conf	0.43	0.48	0.45	0.23	0.59	0.86	0.40	0.58	0.75
P_{fp}	0.60	-	-	-	-	-	0.60	0.65	N/A
P_{fp} Low 90% Conf	0.58	-	-	-	-	-	0.56	0.59	N/A
P_{fp} Upper 90% Conf	0.66	-	-	-	-	-	0.65	0.75	0.00
BAR	0.45	-	-	-	-	-	-	-	-
DISCRIMINATION STAGE									
P_d	0.35	0.30	0.35	0.15	0.40	0.70	0.25	0.45	0.40
P_d Low 90% Conf	0.27	0.24	0.25	0.07	0.29	0.54	0.19	0.32	0.11
P_d Upper 90% Conf	0.40	0.41	0.45	0.21	0.51	0.86	0.35	0.56	0.75
P_{fp}	0.45	-	-	-	-	-	0.45	0.45	N/A
P_{fp} Low 90% Conf	0.41	-	-	-	-	-	0.41	0.37	N/A
P_{fp} Upper 90% Conf	0.50	-	-	-	-	-	0.51	0.54	0.90
BAR	0.30	-	-	-	-	-	-	-	-

Response Stage Noise Level: 10.00

Recommended Discrimination Stage Threshold: 0.50

Summary of Desert Extreme Results (Full Ground Truth)

Metric	Overall	Standard	Nonstandard	By Size			By Depth, m		
				Small	Medium	Large	< 0.3	0.3 to <1	>= 1
RESPONSE STAGE									
P_d	0.30	0.30	0.30	0.10	0.50	0.70	0.25	0.40	0.40
P_d Low 90% Conf	0.27	0.25	0.22	0.07	0.38	0.54	0.20	0.31	0.11
P_d Upper 90% Conf	0.38	0.40	0.41	0.19	0.59	0.86	0.34	0.53	0.75
P_{fp}	0.60	-	-	-	-	-	0.60	0.65	N/A
P_{fp} Low 90% Conf	0.58	-	-	-	-	-	0.56	0.59	N/A
P_{fp} Upper 90% Conf	0.66	-	-	-	-	-	0.65	0.75	0.00
BAR	0.45	-	-	-	-	-	-	-	-
DISCRIMINATION STAGE									
P_d	0.30	0.25	0.30	0.10	0.40	0.70	0.25	0.40	0.40
P_d Low 90% Conf	0.23	0.21	0.22	0.06	0.29	0.54	0.17	0.29	0.11
P_d Upper 90% Conf	0.35	0.35	0.41	0.17	0.51	0.86	0.30	0.50	0.75
P_{fp}	0.45	-	-	-	-	-	0.45	0.45	N/A
P_{fp} Low 90% Conf	0.41	-	-	-	-	-	0.41	0.37	N/A
P_{fp} Upper 90% Conf	0.50	-	-	-	-	-	0.51	0.54	0.90
BAR	0.25	-	-	-	-	-	-	-	-

Response Stage Noise Level: 10.00

Recommended Discrimination Stage Threshold: 0.50

Note: *The recommended stage threshold values are provided by the demonstrator.*

To view the full Scoring Record for this demonstration and for all other demonstrations conducted at the Aberdeen and Yuma Proving Grounds in support of the Standardized UXO Technology Demonstration Sites Program please visit our Web site at: www.uxotestsites.org.